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# Simulating land subsidence in the northern Kanto Plain by coupled groundwater flow/land subsidence model with nested grid scheme


# Masaatsu Aichi[1]; Tomochika Tokunaga[2]

[1] Dept. Geosystem Eng., Univ. Tokyo; [2] Dept. Environment Systems, Univ. Tokyo



In the northern part of the Kanto Plain, near the prefectural boundaries among Tochigi, Ibaraki and Saitama Prefectures, the observed hydraulic potentials of the aquifers are shown to be nearly steady state or slightly increasing with clear seasonal fluctuations. On the other hand, the land subsidence has been observed. The land subsidence tends to be observed from spring to summer in accordance with the seasonal drop of the hydraulic potential while the slight expansion is observed from autumn to winter in accordance with the rise of the hydraulic potential. Here, we constructed a model with the following two assumptions to explain the observed data, i.e., the soil deforms plastically in the case where effective stress exceeds the past maximum effective stress, and the low permeability of clayey layers causes the effective stress in the layer to be smaller than that estimated from the hydraulic potential of the surrounding aquifers by cyclic change of the potentials. Based on these assumptions, we adopted the Cam-clay model for the deformation of clayey layers and used the fine gridding in clayey layers to precisely calculate the change of the hydraulic potential in the layers. In the studied area, the aquifer system has been considered to be continuous for the most part of the Kanto Plain and it is difficult to set proper boundary conditions of the smaller scaled model. On the other hand, constructing the regional model including whole aquifer system with the higher spatial resolution is difficult and impractical because of the extensive computational load. In addition, the coupled modeling with higher spatial resolution is not necessary for the whole aquifer system because land subsidence has occurred in limited areas. Then, we conducted the land subsidence simulation by the nested model which integrates the regional groundwater flow model for the whole aquifer system in the Kanto Plain and the coupling groundwater flow/land deformation model for the northern part of the Kanto Plain.

The simulated hydraulic potentials in the aquifers were consistent with the observed data, and the simulated land subsidence was also consistent with that measured by leveling survey. This result suggests that the deformation and hydraulic characteristics of the clayey layers applied in this study can explain the behaviors of the aquifer/aquitard system studied, including subsidence. Based on our results, land subsidence could occur in accordance with the seasonal change of hydraulic potentials where thick clayey layers exist. Thus, not only controlling the amount of groundwater abstraction but also the effects of seasonal change of hydraulic potentials should be taken into consideration to prevent land subsidence. Also, pre-consolidation stress will reach the value corresponding to the seasonal minimum of the hydraulic potential in longer term. Then, the effect of seasonal change of hydraulic potentials on land subsidence will be minimized in the long term.